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JAMMING PERFORMANCE OF INFRARED BAIT/CHAFF

Pang Gongpei

The effectiveness of infrared guidance and radar guidance jamming with infrared bait and chaff has been proven in modern high-tech warfare. Their jamming regime relies on infrared radiation of the infrared bait, and radar reflective waves from chaff to simulate the target (such as aircraft, warships, tanks, and point targets) performance to confuse, disturb, and jam the infrared guidance and radar guidance, as well as their probing and aiming systems. In tactical applications, these are divided into centroid mode, dump mode, dilution mode, and confusion mode. Study of the jamming performance of infrared bait and chaff is required in developing the smoke, flame, light, and electric/sourceless jamming technologies. It is very important and practical to enhance the jamming performance of infrared bait and chaff, as well as to extend the jamming frequency spectrum.

1. Experiments and Results

1.1. Experiments for increasing radiation intensity of Mg-Teflon composite

Mg-Teflon infrared bait has been extensively applied. The enhancement of jamming performance is because of a further increase in the radiation intensity (I_{λ}) in the corresponding

wave band. However, for a chemical agent containing only the Mg-Teflon constituent, it is difficult to further increase the radiation intensity in a specified wave band (3 to 5 μ m or 8 to 14 μ m) by only adjusting the proportion of two constituents. As is well known, for chemical agents containing metal combustibles (such as Mg and Al), the combustion radiation is of selective radiation. With appropriate compounding, the light spectral emission rate in a certain wave band not only can exceed that of a graybody, but also that of a near-blackbody. Therefore, it is possible to further increase the spectral emission rate by selecting with sieving some additives into the Mg-Teflon composite to promote the spectral emission rate in the wave bands of 3 to 5 μ m or 8 to 14 μ m. As discovered in experimental studies, by selecting with a sieve some metals or nonmetallic materials as additives to be added to the compounding formula of the Mg-Teflon composite, this can simultaneously increase the radiation intensities in the range between 3 to 5 μ m and 8 to 14 μ m. As indicated in experimental studies, it is better to add Fe₃O₄ at the wave band between 3 and 5 μ m. In the wave band of 8 to 14 μ m, it is better to add Mg-Al. Table 1 shows the experimental results. For the specimen agent in the experiment, the column density is 1.82g/cm³; its diameter is 30mm. In the case of terminal surface combustion, the value of I_{3-5 μ m} and I_{8-14 μ m} are simultaneously measured by an SHF-IB double-channel infrared radiation meter. In the identical experimental conditions, I_{3-5 μ m}=421W/sr, and I_{8-14 μ m}=141W/sr, for the Mg-Teflon agent (in chemical measurement compounding ratios, Mg is 45% and Teflon is 55%).

(1) With respect to Mg-Teflon composite with Fe₃O₄ as additive, experiments on the jamming performance of infrared bait in the wave band 3 to 5 μ m were conducted. During the experiments, the OD51mm jamming product round was made of 550g of such agent. Fig. 1 shows the relation between the I_{3-5 μ m} value and the jamming persistence time t. As indicated from the I_M-t

TABLE 1. Experimental Results of Passive Jamming for Millimeter Waves

样品号 a	添加剂材料 b	$I_{\Delta\Delta} / W \cdot sr^{-1}$		C	相对 Mg-Teflon 的增量 $\Delta I_{\Delta\Delta} / W \cdot sr^{-1}$	
		$I_{3 \sim 5 \mu m}$	$I_{8 \sim 14 \mu m}$		$I_{3 \sim 5 \mu m}$	$I_{8 \sim 14 \mu m}$
1	Fe	520	215		99	74
2	Ti	580	236		159	95
3	Cu	470	231		49	90
4	Si	480	211		59	70
5	Mg-Al	625	265		204	124
6	C	430	199		9	58
7	Zn	495	216		74	75
8	Fe ₂ O ₃	435	146		14	5
9	Fe ₃ O ₄	630	182		209	41
10	TiO ₂	435	155		14	14
11	CuO	585	165		164	24
12	Co ₂ O ₃	475	177		54	36
13	MgO	601	189		180	48
14	SiO ₂	530	162		109	21
15	WO ₃	444	168		23	27
16	ZrO ₂	490	145		69	4
17	CaF ₂	422	161		1	20
18	TiC	540	205		119	64

KEY: 1 - sample number 2 - additive materials
3 - increment $I_{\Delta\Delta} / W \cdot sr^{-1}$ relative to Mg-Teflon

performance curve in the figure, for the jamming persistence time between 0 and 25s, the $I_{3 \sim 5 \mu m}$ value maintains at 2000W/sr and higher. When the jamming time persists to 45s, the $I_{3 \sim 5 \mu m}$ value also approaches 2000W/sr. During the experiments on multiple jamming effect on the guidance head of 3 to 5 μm by the jamming round, the

jamming response time is only 0.4s, and all jamming success rates are 100%.

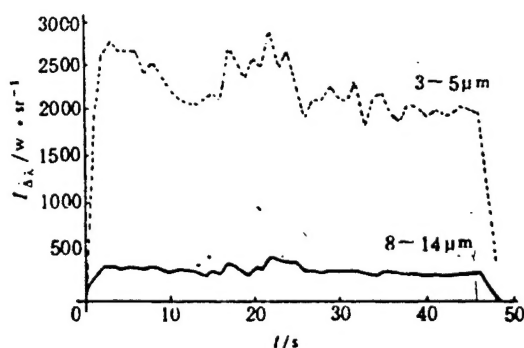


Fig. 1. Curve $I_{\lambda\lambda}$ -t of Mg-Teflon composite containing Fe_3O_4 additive

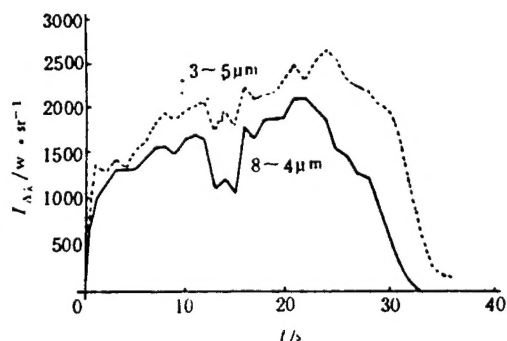


Fig. 2. Curve $I_{\lambda\lambda}$ -t of Mg-Teflon composite containing Mg-Al additive

(2) With respect to jamming performance experiments with infrared bait with Mg-Teflon composite with Mg-Al as additive were conducted in the wave band between 8 and 14 μm . During the experiments, an OD67mm product jamming round was prepared from 600g of such agent. Fig. 2 shows the relationship between the $I_{8\sim 14\mu\text{m}}$ value and the jamming persistence time. As indicated in the $I_{\lambda\lambda}$ -t performance curve in the figure, the maximum value of $I_{8\sim 14\mu\text{m}}$ exceeds 2000W/sr. Within the persistence jamming time of 0 to 30s, the mean value of $I_{8\sim 14\mu\text{m}}$ is 1440W/sr. However, the simultaneously produced $I_{3\sim 5\mu\text{m}}$ also exceed 1800W/sr.

1.2. Jamming Performance Experiments with Chaff Materials and Their Results

(1) Static-rate radar reflective area and bandwidth experiments for several millimeter-wave chaffs were conducted. By selecting several made-in-China chaffs, by using the quasi-single station RCS comparative method in a microwave dark chamber

for conducting experimental studies on single-filament static state radar-reflective area and bandwidth experiments, the results were obtained that are shown in Table 2. As indicated in the experiments, the RCS of the V-type aluminum chaff is the

TABLE 2. RCS and Frequency Bandwidth of Static Single Chaff for Certain Centimeter-Wave Chaffs

样品号 a	b 样品名称		RCS/cm ²	带宽(%) c
1	2 mm×1 mm 矩型铝箔条 d		5.03	14.3
2	4 mm×1 mm 矩型铝箔条 d		6.37	18.8
3	8 mm×1/2 mm V型铝箔条 e		8.50	15.0
4	镀铝玻璃纤维 f		5.35	12.5
5	中空镀铝玻璃纤维(半包覆型) g		4.59	15.5

KEY: a - specimen number b - name of specimens
c - bandwidth d - rectangular type aluminum chaff
e - V-type aluminum chaff f - aluminum-coating glass fiber
g - hollow aluminum-coated glass fiber (semi-enveloping type)

largest. For 4mmx1mm rectangular aluminum chaff, the bandwidth frequency response is high.

(2) Experiments were conducted on millimeter wave static state radar-reflective area L of several type of chaffs. Based on quasi-wave theory, several types of chaffs, which have been applied in centimeter wave jamming, were cut into chaff for jamming 8mm waves in the measurement tests on static-state radar-reflective area L, with the results as shown in Table 3. In the experiments, 8mm wave doppler radar (working frequency 34.67GHz), developed at the Nanjing University of Science and Technology, was tested with the corresponding method.

As indicated in the experiment, a metal oscillator with its length equal to one-half wavelength of the electromagnetic wave

has the highest reflectivity L for millimeter waves. Besides, owing to good electroconductivity of the material for V-type

TABLE 3. Static Test for RCS Values for Certain Millimeter-Wave Chaffs

样品号 a	样品名称 b	c	长度/mm	根 数 d	V_m/mV	RCS/mm ²
1	全包覆镀铝玻璃纤维 e		4.3	95	1.26	84.00
2	半包覆镀铝玻璃纤维 f		4.3	102	0.86	36.45
3	中空覆镀铝玻璃纤维 g		4.3	100	0.60	18.10
4	4 mm×1 mm 矩型铝箔条 h		4.3	109	1.20	66.41
5	8 mm×1/2 mm V 型铝箔条 i		4.3	110	1.66	125.92
6	全包覆镀铝玻璃纤维 e		3.0	110	0.40	7.31
7	全包覆镀铝玻璃纤维 e		5.5	106	0.42	8.36
8	全包覆镀铝玻璃纤维 e		6.7	104	0.90	7.73
9	标准球 j				0.50	

KEY: a - specimen number b - name of specimens
 c - length d - number of pieces e - fully-enveloping aluminum-coated glass fiber
 f - semi-enveloped aluminum-coated glass fiber
 g - hollow aluminum-coated glass fiber
 h - rectangular type aluminum chaff
 i - V-type aluminum chaff j - standard ball

aluminum chaff with larger cross-sectional area width, its RCS performance is better.

(3) Passive radar jamming experiments with millimeter-wave chaff were conducted. In the experiments, a model Fs6 radiation meter of 8mm wave band, developed by the Close-Range sensing Research Institute of Millimeter Waves and Light Waves at the Nanjing University of Science and Technology was used in the experiments. Chaffs with different specifications were cut into sizes 4mm in length and was randomly adhered at different densities (piece/cm²) and in different directions on a foam plastic 45cm x 45cm in size. A conical scanning probe (30° incident angle and 3r/s in speed of the conical scanning probe)

with the specimen board was tested with the F36 radiation meter. The experimental results are shown in Table 4.

TABLE 4. Experimental Results of Passive Jamming for Millimeter Waves

样品号 a	样品名称 b	c	箔条密度/根·cm ⁻² d	幅值/mV e	等效相对强度
0	金属板 f			200	1.00
1	全包覆镀铝玻璃纤维 g		88	170	0.85
2	全包覆镀铝玻璃纤维 g		75	160	0.80
3	全包覆镀铝玻璃纤维 g		38	80	0.40
4	半包覆镀铝玻璃纤维 h		50	120	0.60
5	中孔镀铝玻璃纤维 i		50	120	0.60
6	4 mm×1 mm 矩型铝箔条 j		50	140	0.70
7	8 mm×1/2 mm V型铝箔条 k		50	160	0.80

KEY: a - specimen number b - name of specimen
 c - chaff density/piece·cm⁻² d - radiation value
 e - equivalent relative intensity f - metal plate
 g - fully enveloped aluminum-coated glass fiber
 h - semi-coated aluminum covered glass fiber
 i - hollow aluminum coated glass fiber
 j - rectangular type aluminum chaff k - V-type aluminum chaff

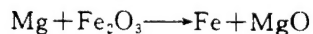
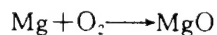
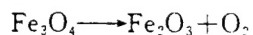
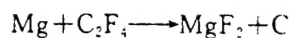
As indicated in the experiments, when the chaff density is 50 pieces per cm², out of several types of chaff material the V-type has the greatest jamming relative intensity. The greater the chaff density, the greater is the equivalent relative intensity.

2. Discussion and Conclusions

2.1. Regime for Raising I_{Δ} of Mg-Teflon Containing Certain Additives

From Table 1 we know that there are increases to differing extent in $I_{3.5\mu m}$ and in $I_{8.4\mu m}$ values after certain additives are blended into the Mg-Teflon composite. There are possibly two

reasons for this fact: first, the additive takes part in the combustion reaction process, and generates the corresponding radiators of 3 to 5 μ m and 8 to 14 μ m, thus constituting the superimpositioning of energy. Second, the additive is activated and excited during the combustion reaction process with molecular rotation, oscillation, or energy-level electron jumps in the outer atomic shells, thus generating infrared radiation in the wave bands 3 to 5 μ m and 8 to 14 μ m. This also constitutes superimpositioning of energy, and an increase of total radiative energy. For example, by using Fe_3O_4 as an additive to blend into the Mg-Teflon composite, the following reactions are possible:



It can be seen that after Fe_3O_4 is blended, the original reaction products $\text{MgF}_2 + \text{C}$ become a system of equal radiators: MgF_2 , C, Fe_2O_3 , Fe_3O_4 , MgO , FeF_3 , and CO. However, the specific radiation rate is higher in the waveband of 3 to 5 μ m for Fe, Fe_2O_3 , Fe_3O_4 , and MgO . Even not considering the activation and excitation of the additive resulting in the superimpositioning of infrared energy, an increase in I_{λ} is also apparent.

2.2. On Enhancing the Jamming Performance of Centimeter-Wave Chaff

From Table 2, to enhance the jamming performance of the same type of chaff material (aluminum chaff), the RCS and the frequency response bandwidth can also be enhanced by changing the geometric dimensions of the body. Studies on further developing this aspect will promote the enhancement of jamming performance for centimeter-wave chaff.

2.3. Effectiveness of millimeter-wave jamming by available centimeter-wave jamming chaff

As indicated from the experimental results in Table 4, for the available centimeter-wave jamming chaff cut into millimeter-wave jamming chaff according to quasi-wave theory, it is similarly effective with millimeter-wave jamming.

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